Japanese Patent Laid-Open Publication No. 2-192826

SPECIFICATION

1. Title of the Invention

Bulging Method

2. Claims

(1) A bulging method for bulging a metal plate into a worked part in a predetermined shape by use of a press die, wherein simultaneously with formation of the worked part, a stress corresponding to a tensile stress acting on a bent portion at a base end of the bulged worked part is applied so as to compress and deform the bent portion in a bulging direction.

3. Detailed Description of the Invention

[Objects of the Invention]

(Technical Field of the Invention)

The present invention relates to a bulging method for bulging a metal plate into a worked part, such as a patterned part, a component fitting part or the like.

(Prior Art)

Conventionally, in order to form a metal panel for building provided with a bulged pattern, for example, in order to bulge a metal plate 100 into a worked part 101 in the shape of a rectangular ingot case as shown by Fig. 17, a press die as shown by Fig. 16 has been used.

The press die comprises a die 102 with a hollow forming part 102a as a fixed lower mold, and a punch 103 and a blank holder 104 as a movable upper mold. The blank holder 104 encloses the punch 103,

and when the upper mold is moved down, the holder 104 moves ahead of the punch 103.

In the press die, a metal plate 100 is placed on the die 102, and the upper mold is moved down. Then, the blank holder 104 presses the metal plate against the die 102, and subsequently the punch 103 comes into the forming part 102a. Thus, the metal plate 100 obtains the worked part 101 bulged between the punch 103 and the die 102.

(Problems to be Solved by the Invention)

In the art of bulging, one of the causes of molding failure is elasticity recovery. In the above-described case, a tensile stress acts on the worked part 101 during the bulging, and especially, the tensile stress acting on a bent portion S (see Fig. 16) which is a base end of the bulged portion is the strongest. Therefore, after taken out from the press die, the bulged top portion is apt to return toward the base end by elasticity recovery of the other parts than the bent portion S. This deformation of the worked part 101 influences the non-worked parts, and the metal plate 100 may have surface distortion, such as a bend, a twist, an accretion, and may be wholly curved in an opposite direction to the bulging direction. Especially when a large number of worked parts 101 are arranged into a pattern, the curve occurs to a great degree, and the formation accuracy of the product will be largely degraded. This is a significant problem, and it has been a task to solve this problem. Also, there is possibility that the above-described surface distortion may be caused by residual tensile stress on the bent portion S, and the degree of the residual tensile stress depends on the configuration of the worked part 101; however, anyway, the cause of the surface distortion is an uneven distribution of tensile stress in the worked part 101.

In order to avoid the molding failure, there is a case where the die is designed in consideration for elasticity recovery. However, the

design must be carried out by a designer skilled enough, and moreover, there are cases where it is impossible to prevent surface distortion completely due to the configuration of the worked part. Further, in order to prevent deformation of the non-worked parts also, a bead is provided for the blank holder, or the pressure of the blank holder is strengthened. However, these countermeasures are not effective enough to prevent surface distortion, and especially the countermeasure that a bead is provided for the blank holder results in making an indentation, which is undesired when the worked part is to be formed as a pattern.

(Object of the Invention)

The inventors have made the present invention paying attention to the above-described problems. An object of the present invention is to provide a bulging method which achieves a good product with high formation accuracy without requiring complicate die design in consideration for elasticity recovery.

[Structure of the Invention]

(Means for Solving the Problems)

A bulging method according to the present invention is a method for bulging a metal plate into a worked part in a predetermined shape by use of a press die, wherein simultaneously with formation of the worked part, a stress corresponding to a tensile stress acting on a bent portion at a base end of the bulged worked part is applied so as to compress and deform the bent portion in a bulging direction. This structure solves the above-described problems.

The compressing stress corresponding to the tensile stress can be designed by the amount of compression applied to the metal plate in the thickness direction and the width of a portion to be compressed. For example, by providing the punch with a compression part with these dimensions, the compressing stress can be achieved at the time

of bulging.

(Operation of the Invention)

In the bulging method according to the present invention, simultaneously with formation of the worked part, the bent portion at the base end of the worked part where the tensile stress is the strongest is compressed and deformed by a stress corresponding to the tensile stress. The compressing stress in the thickness direction of the metal plate offsets the tensile stress, prevents elasticity recovery of the bulged top portion from influencing non-worked parts and further prevents the entire surface distortion of the metal plate.

(Embodiments)

First Embodiment

Figs. 1-3 show an exemplary press die used for carrying out a bulging method according to the present invention. The first embodiment describes a case wherein a metal plate P which is an aluminum alloy plate with a specified thickness t is bulged at a worked part C into a rectangular ingot case with a bulging top portion A and an inclined portion B with a specified rising angle $\theta 0$.

The press die 1 has, as a fixed lower mold, a die 3 with a forming part 2 which is a concavity corresponding to the worked part C, and has, as a movable upper mold, a punch 4 and a blank holder 5 enclosing the punch 4. The blank holder 5 is suspended by a retainer or an elastic member (not shown) at a position to face a pressing surface 6 of the die 3, and when the upper mold moves down, the blank holder 5 moves ahead of the punch 4.

The forming part 2 has a flat bottom 7 and an inclined surface 8 extending from the bottom 7 to a shoulder part 10 which is a bolder to the pressing surface 6 at a specified angle θd. On the entire periphery of a lower surface of the punch 4, a stepped compression part 9 is formed as means for compressing and deforming a bent

portion S at a base end of the worked part C in the bulging direction (downward) with a stress corresponding to a tensile stress acting on the bent portion S. The compression part 9 faces the shoulder part 10 of the die 3, and the compression part 9 has such a protruding dimension and such a width to compress the bent portion S when the upper die reaches the dead end.

A metal plate P is placed on the die 3. Then, as the upper mold is being moved down, the metal plate P is nipped hard between the blank holder 5 and the pressing surface 6, and subsequently the worked part C is bulged between the punch 4 and the die 3 while the bent portion S at the base end of the worked part C is compressed between the compression part 9 and the shoulder part 10. At this time, a tensile stress acts on the worked part C, and especially the tensile stress on the bent portion S is the strongest. However, the tensile stress is offset by a compressive stress in the direction of thickness of the metal plate generated by the holding between the compression part 9 and the shoulder part 10. Also, the compressive deformation causes a flow of the plate thickness toward the bulging top portion, which restrains elasticity recovery at the bulging top portion.

Second Embodiment

Figs. 4-6 show another exemplary press die used for carrying out a bulging method according to the present invention. The same parts as those of the press die used for the first embodiment are provided with the same reference symbols, and descriptions thereof are omitted.

In the press die 15 used for the second embodiment, as shown by the dashed lines in Figs. 4, 5 and 6, the compression part 9 of the punch 4 is located exactly above the shoulder part 10. Thereby, in the press die 15, the width b of the compression part 9 is larger than

that of the compression part 9 in the first embodiment (see Fig. 3).

An experiment was conducted, wherein a large number of worked parts C in arrangement were formed on the metal plate P by using the press die 15 while the protruding dimension a and the width b of the compression part 9 and the angle θd of the inclined surface 8 of the forming part 2 were varied.

The metal plate P was an aluminum alloy (A1100P-H14) with a thickness t of 2mm, and it was 1000mm by 1000mm large. The worked part C was designed as shown by Figs. 7-9. The bulging top portion A had longer sides e1 of 59mm and shorter sides f1 of 5mm, and the base end had longer sides e2 of 68mm and shorter sides f2 of 14mm. The bulging dimension h was 2mm, and the rising angle θ0 of the inclined surface B was 24 degrees. On the metal plate P, a total of 280 worked parts C were formed such that 28 rows of worked parts C are arranged at regular intervals of 15mm in the direction of the shorter sides, each row having 10 worked parts C arranged at regular intervals of 15mm in the direction of the longer sides. The direction of the shorter sides is referenced by X direction, and the direction of the longer sides is referenced by Y direction.

The worked parts C were formed sequentially from a side with a pressure of 30t. Then, while the dimensions of the compression part 9 and the forming part 2 were varied, the worked parts C were formed on a plural number of metal plates P. Thereafter, bends of the metal plates P after the molding were measured. More specifically, as Fig. 10 shows, three strings 11 were bridged in parallel between opposite sides of each plate P, and the maximum distance between each of the strings and the surface of the plate P was measured. In this embodiment, because there are no significant differences among the measurement results at the three points, the maximum distance between the middle string 11 and the surface of

the plate P was treated as a central value. Also, as Fig. 11 shows, a bend of the plate P in the opposite direction to the bulging direction at the worked part C is represented by a positive value, and a bend of the plate P in the bulging direction is represented by a negative value.

Figs. 12-14 show the results. It is apparent from the results of the experiment that as the protruding dimension a and the width b of the compression part 9 become larger, the bend in the X direction is changing from the positive side to the negative side. Also, it is apparent that as the difference between the angle θd of the inclined surface of the forming part 2 and the rising angle θ0 of the worked part C becomes larger, the bend in the X direction becomes larger mainly in the positive side. Regarding the Y direction, the bends in all the cases were 10mm or less, and so large a deformation to deteriorate the formation accuracy did not occur.

When the compression part 9 had a protruding dimension a within a range from 0.45mm to 0.55mm and had a width b within a range from 1.8mm to 2.2mm, and when the difference between the angle θd of the inclined surface of the forming part 2 and the rising angle θ0 (24 degrees) of the worked part C was within a range from 0 degree to 15 degrees, the bend in the X direction and the bend in the Y direction were both 10mm or less, that is, the formation accuracy was sufficiently high, and products with no local bends, twists or accretions could be obtained.

As in the second embodiment, by using the press die 15 with the compression part 9 located exactly above the shoulder part 10, better products could be obtained. This is because the width b of the compression part 9 could be easily set to a fit value (within a range from 1.8mm to 2.2mm) due to the structure of the press die 15 and because the area in and around the bent portion S was compressed enough to obtain so large a compressive stress to offset a tensile

stress.

The dimensions of the press die shown above, of course, changes in accordance with the material and the dimensions of the metal plate and the worked part. The configuration of the worked part may be a square, a circle or a more complicated shape as well as a rectangle, and there are no particular limitations. The compression part 9 may be configured into, for example, a protrusion with a trapezoidal section as shown by Fig. 15(a) and (b) and may be configured to have a curved surface. In these cases also, as described above, the protruding dimension and the width of the compression part 9 should be large enough to compress the bent portion S (to actually bite the metal plate) when the upper mold reaches the dead end.

[Effects of the Invention]

As described above, a bulging method according to the present invention is to bulge a metal plate into a worked part in a predetermined shape by use of a press die, and in the method, simultaneously with formation of the worked part, a stress corresponding to a tensile stress acting on a bent portion at a base end of the bulged worked part is applied so as to compress and deform the bent portion in a bulging direction. The invention brings the following effects. Regardless of the shape of the worked part, surface distortion can be prevented, and a good product with high formation accuracy can be obtained. Also, since during the formation of a product, deformation by elasticity recovery can be prevented within the worked part, molding is completed with only one step, and the design of the press die is easy.

4. Brief Description of the Drawings

Figs. 1 and 2 are sectional views of a press die usable for a

method according to the present invention, Fig.1 showing a state where a metal plate is nipped in the press die and Fig. 2 showing a state where the press die operates to mold the metal plate. Fig. 3 is an enlarged view of a bent portion made by the molding shown by Fig. 2. Fig. 4 and 5 are sectional views of another press die usable for the method according to the present invention, and Fig. 6 is an enlarged view of a bent portion made by the molding shown by Fig. 5. Fig. 7 is a plan view showing an arrangement of worked parts on the metal plate. Figs. 8 and 9 show dimensions of each of the worked parts, Fig. 8 being a plan view showing a convex surface and Fig. 9 being a sectional view. Fig. 10 is a perspective view showing a way of measuring a bend of the metal plate. Fig. 11 is an illustration showing directions of the bend of the metal plate. Figs. 12, 13 and 14 are graphs showing variations in the bend in X direction while the protruding dimension and the width of the compression part, the difference between the angle of the inclined surface and the rising angle of the forming part. Figs. 15(a) and (b) are sectional views of other examples of the compression part. Fig. 16 is a sectional view of a conventional press die. Fig. 17 is a plan view of a worked part made by the conventional press die shown by Fig. 16.

1, 15: press die

P: metal plate

C: worked part

S: bent portion

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CLAIMS

1. A pressed optical element produced by press working of a metal plate and having an optical surface usable in a catoptric system, wherein a reference part which serves as a reference when the optical element is incorporated into the catoptric system is formed by drawing.

2. A pressed optical element produced by press working of a metal plate and having an optical surface usable in a catoptric system, wherein a dimension of a reference part in a direction along an optical axis, the reference part serving as a reference when the optical element is incorporated into the catoptric system, is larger than a thickness of the metal plate.

3. The pressed optical element according to claim 1 or claim 2, wherein an outer periphery of the reference part is in a shape of a cylinder or a square pole.

4. The pressed optical element according to claim 1 or claim 2, wherein the reference part is divided into three or more protruding parts.

5. The pressed optical element according to claim 1 or claim 2, wherein the metal plate comprises a first soft metal substrate, and a second soft metal substrate which is placed on the first soft metal substrate and which has a higher purity than the first soft metal substrate.

6. The pressed optical element according to claim 5, wherein the soft metal substrates are aluminum substrates.

7. The pressed optical element according to claim 5, wherein the second soft metal substrate is covered with a silicon dioxide film.

8. A method for producing a pressed optical element with an optical surface usable in a catoptric system by press working of a metal plate, said method comprising a step of, after forming the optical surface, shearing the metal plate.

9. A displacement detecting device for detecting information on rotation and travel of a movable object by use of diffraction of light, said device comprising the pressed optical element according to one of the claims 1-7.

10. An image forming apparatus for forming an image on a photosensitive member by scanning a light beam, said apparatus comprising the pressed optical element according to one of the claims 1-7.

DETAILED DESCRIPTION OF THE INVENTION

[0001]

[Field of the Invention]

The present invention relates to a pressed optical element which is produced by press working of a metal plate and which has an optical surface usable in a catoptric system, and a manufacturing method thereof.

[0002]

[Description of Prior Art]

Well-known methods for producing an optical element for catoptric systems are a method wherein a glass material is processed mechanically, for example, by grinding and/or polishing and a method wherein a metal reflecting coating is formed on a plastic material by vapor deposition or the like. The most convenient method for producing such an optical element is a method disclosed by Japanese Patent Laid-Open publication No. 8-36222, wherein a metal plate with a high reflectivity is pressed. In this method, the metal plate is pressed only into an optical surface, and thereby, a curve mirror merely for reflecting an image is formed.

[0003] In the meantime, as a high-accuracy optical element to be incorporated in an optical device, a pressed mirror 1 shown by Fig. 15 is well known. The pressed mirror 1 has an optical surface support part 3 inside a flat part 2, and the rim of the flat part 2 serves as a reference face 4 when the pressed mirror 1 is fitted into an optical device.

[0004] The pressed mirror 1 is produced by a typical progressive pressing method as shown by Fig. 16(a)-(c). More specifically, in a first step shown by Fig. 16(a), a right reference hole 5a and a left reference hole 5b are made in a metal plate M, which is in the shape of a strip or a hoop, by shearing. In a second step shown by Fig. 16(b), the optical surface support part 3 is formed in the center of the flat part 2 by plastic deformation while using the holes 5a and 5b as references. In a third step shown by Fig. 16(c), spaces 7a and 7b are made by stamping in the right and left sides of the flat part 2 with tie bars 6a and 6b remained, so that the flat part 2 is half supported by the metal plate M via the tie bars 6a and 6b. The second step and the third step may be reversed.

[0005] The conventional pressed mirror 1 is conveyed while being

held by the metal plate M via the tie bars 6a and 6b, and when necessary, the conventional pressed mirror 1 is separated from the metal plate M by cutting the tie bars 6a and 6b. Thereafter, the pressed mirror 1 is incorporated into an optical device with the reference face 4 of the pressed mirror 1 used as a reference. Thus, the reference holes 5a and 5b guarantee the accuracy of the optical surface support part 3, and the reference face 4 is used as a reference when the pressed mirror 1 is incorporated into an optical device and guarantees the accuracy of the positioning of the optical surface support part 3 in the optical device.

[0006]

[Problems to be Solved by the Invention]

Now referring to Fig. 17, problems in producing the conventional pressed mirror 1 are briefly described from an aspect of one-dimensional direction. The reference holes 5a and 5b which are formed in the middle of the manufacturing process of the pressed mirror 1 are temporary references. If there is a processing error of δ1 between the reference holes 5a, 5b and the optical surface support part 3, and if there is a processing error of δ2 between the reference holes 5a, 5b and the reference face 4, a processing error δp against the reference face 4 will be, in the worst case, δ1+δ2. Further, if there is a positioning error δA when the pressed mirror 1 is incorporated into an optical device, there will be a final error δ=δ1+δ2+δA. Thus, all the processing errors δp and the positioning error δA are accumulated, and production of a high-accuracy pressed mirror 1 is very difficult.

[0007] Moreover, chips, flash, warp, etc. are caused by the shearing in the first step of forming the reference holes 5a and 5b, and the chips, flash, warp, etc. are carried to the second step and enlarge the processing error in the second step. If the chips are stuck during the formation of the optical surface support part 3, formation of a

high-accuracy optical surface is impossible.

[0008] Further, the thinnest possible material is used for the pressed mirror 1 so that the pressed mirror 1 can be engaged with an engagement recess Sa of a holder portion S of the optical device (see Fig. 18), so that the metal plate M will function as a structure satisfactorily and so that the press working will be easy. Therefore, the reference face 4 of the pressed mirror 1, after the shearing and the drawing, has a small dimension in a direction along the optical axis, that is, the engagement length of the pressed mirror 1 is short. Due to this fact, a tilt at an angle of θ occurs when the pressed mirror 1 is fitted into the engagement recess Sa.

[0009] Additionally, because flash, warp, etc. occur on the reference face 4, a gall is likely to occur when the pressed mirror 1 is engaged with the engagement recess Sa, and thus, it is difficult to fit the pressed mirror 1 into the engagement recess Sa. When the pressed mirror 1 is put in the engagement recess Sa with a gall, the optical surface support part 3 is deformed.

[0010] Also, a material with a high purity is selected as the metal plate M so as to guarantee the reflectivity of the pressed mirror 1. The higher the purity of the metal plate M is, the lower the rigidity is while the higher the reflectivity is. Therefore, it is difficult to guarantee the metal plate M for both reflectivity and rigidity. Also, when the purity of the metal plate M is high, that is, when the reflectivity is high, the metal plate M is more likely to be oxidized, and the resistance of the metal plate M against the circumstances is weak.

[0011] It is an object of the present invention is to provide a pressed optical element which does not have the problems above, which has a high-accuracy optical surface and which can be incorporated into an optical device accurately, and a method for

producing the pressed optical element.

[0012]

[Means for Solving the Problems]

In order to achieve the object, the invention in claim 1 is a pressed optical element produced by press working of a metal plate and having an optical surface usable in a catoptric system, wherein a reference part which serves as a reference when the optical element is incorporated into the catoptric system is formed by drawing.

[0013] The invention in claim 2 is a pressed optical element produced by press working of a metal plate and having an optical surface usable in a catoptric system, wherein a dimension of a reference part in a direction along an optical axis, the reference part serving as a reference when the optical element is incorporated into the catoptric system, is larger than a thickness of the metal plate.

[0014] The invention in clam 3 is the pressed optical element according to claim 1 or claim 2, wherein an outer periphery of the reference part is in a shape of a cylinder or a square pole.

[0015] The invention in claim 4 is the pressed optical element according to claim 1 or claim 2, wherein the reference part is divided into three or more protruding parts.

[0016] The invention in claim 5 is the pressed optical element according to claim 1 or claim 2, wherein the metal plate comprises a first soft metal substrate, and a second soft metal substrate which is placed on the first soft metal substrate and which has a higher purity than the first soft metal substrate.

[0017] The invention in claim 6 is the pressed optical element according to claim 5, wherein the soft metal substrates are aluminum substrates.

[0018] The invention in claim 7 is the pressed optical element according to claim 5, wherein the second soft metal substrate is

covered with a silicon dioxide film.

[0019] The invention in claim 8 is a method for producing a pressed optical element with an optical surface usable in a catoptric system by press working of a metal plate, said method comprising a step of, after forming the optical surface, shearing the metal plate.

[0020] The invention in claim 9 is a displacement detecting device for detecting information on rotation and travel of a movable object by use of diffraction of light, said device comprising the pressed optical element according to one of the claims 1-7.

[0021] The invention in claim 10 is an image forming apparatus for forming an image on a photosensitive member by scanning a light beam, said apparatus comprising the pressed optical element according to one of the claims 1-7.

[0022]

[Embodiments of the Invention]

The present invention will be described in details referring to Figs. 1-14. Fig. 1 is a plan view of a pressed optical element 11 according to a first embodiment, and Fig. 2 is a sectional view of the pressed optical element 11. The pressed optical element 11 is, for example, a concave mirror and is formed by press working of a metal plate in the shape of a strip or a hoop. The pressed optical element 11 has a cylindrical reference part 12, and for example, the outer circumferential surface of the cylindrical reference part 12 serves as a reference face 13. An optical surface support part 15, which is, for example, concave, is formed on an upper flat surface 14 above the reference part 12, and for example, an upper surface of the optical support part 15 is an optical surface 16. At a lower end of the reference part 12, a flange 17 is provided.

[0023] Here, the reference face 13 serves as a reference at the time of forming the optical surface support part 15 and at the time of

incorporating the pressed optical element into an optical device. The pressed optical element 11 may be a spherical mirror, an elliptic mirror, a parabolic mirror, an aspherical mirror, a free curved surface mirror or the like. Also, needless to say, the inner circumferential surface of the cylindrical part 12 may be a reference face.

[0024] Fig. 3 shows a composition of a metal plate A which is used as the material of the pressed optical element 11. The metal plate A is a laminate of a first aluminum substrate A1 in a lower layer and a second aluminum substrate A2 in an upper layer. The first aluminum substrate A1 has an aluminum constituent of, for example, 99% and has a thickness of, for example, 0.8mm. The second aluminum substrate A2 has an aluminum constituent of, for example, not less than 99.8% and has a thickness of, for example, 0.2mm. The first aluminum substrate A1 and the second aluminum substrate A2 are formed by rolling.

[0025] The more the aluminum constituent of the second aluminum substrate A2 is, that is, the higher the purity of the second aluminum substrate A2 is, the higher the reflectivity or the reflection directivity is, while the lower the mechanical rigidity is. However, the first aluminum substrate A1 supplements the rigidity of the second aluminum substrate A2, and the second aluminum substrate A2 can be designed to guarantee the reflective directivity.

[0026] Further, by covering the second aluminum substrate A2 with a silicon dioxide glass film as shown by Fig. 4, the antiweatherability as well as the reflection directivity of the metal plate A can be improved. For forming the glass film A3, a solution mainly constituting hydroxysilane is applied to the second aluminum substrate A2 by coating, dipping or spraying, and the solution is sintered under temperature of 150℃ to 450℃. The glass film A3 formed in this way has less pores than a glass film formed by vapor

deposition, and the glass film A3 prevents penetration of steam well. Therefore, oxidation and corrosion of the second aluminum substrate A2 are prevented, and the antiweatherbility is improved.

[0027] Fig. 5(a)-(c) shows a manufacturing process of the pressed optical element 11. In a first step shown by Fig. 5(a), the cylindrical reference part 12 is formed by drawing of the metal plate A. At this step, the metal plate A is plastic-deformed. Then, the outer circumferential surface of the reference part 12 becomes a reference face 13, and a flat portion 14 is remained over the reference part 12. In a second step shown by Fig. 5(b), the optical surface support part 15 is formed in the center of the flat part 14 with the reference face 13 used as a reference, and the upper surface of the optical surface support part 15 becomes an optical surface 16. In a third step shown by Fig. 5(c), spaces 19a and 19b are stamped around the ring-shaped flange 17 with tie bars 18a and 18b remained. Thus, a pressed optical element 11 with a flange 17 half supported by the metal plate A via the tie bars 18a and 18b is produced.

[0028] The tie bars 18a and 18b are to convey the pressed optical element 11 easily. Therefore, in incorporating the pressed optical element 11 into an optical device, first, the pressed optical element 11 is separated from the metal plate A by cutting the tie bars 18a and 18b. Then, as Fig. 6 shows, by engaging the reference part 12 of the pressed optical element 11 with the engagement recess Sa of the holder portion S of the optical device, the pressed optical element 11 is incorporated into the optical device.

[0029] In the first embodiment, the pressed optical element 11 is produced with the reference face 13 used as a reference, and the pressed optical element 11 is incorporated into the optical device with the reference face 13 used as a reference. Therefore, the pressed optical element 11 can be produced accurately, and the pressed optical

element 11 can be incorporated into the optical device in an accurate position.

[0030] The reason is briefly described from an aspect of one-dimensional direction. Because the optical surface support part 15 is formed with the reference face 13 used as a reference, the processing error δp is only $\delta 1$ as shown by Fig. 7. If the positioning error which occurs when the pressed optical element 11 is incorporated into the optical device is δA, the final error δ will be $\delta 1+\delta A$. Thus, the fitting accuracy is highly improved.

[0031] Also, in the first step, only drawing, that is, plastic deformation of the metal plate A is carried out, and chips, flash, warp, etc. do not occur. Therefore, the optical surface support part 15 can be formed highly accurate. The reference face 13 can be formed such that the dimension of the reference face 13 along the optical axis, that is, the engagement length with the engagement recess Sa is larger than the thickness of the metal plate A. Therefore, the tilt $\theta 1$ of the optical surface support part 15 which occurs when the pressed optical element 11 is incorporated into the optical device is much smaller than the tilt θ of the conventional pressed optical element shown in Fig. 18.

[0032] Further, there is no possibility that flap, warp, etc. may prevent accurate fitting of the pressed optical element 11 into the optical device, and the fitting of the pressed optical element 11 is easy. Moreover, because the rigidity of the reference part 12 is higher than an ordinary single plate, there is no possibility that the reference part 12 may bend when the pressed optical element 11 is fitted into the holder portion S. Therefore, the accuracy of the optical surface 16 of the pressed optical element 11 after fitted into the holder portion S can be guaranteed. Also, the pressed optical element 11 can be fitted easily into a holder portion S' made of a thin plate such as a pressed

sheet metal (see Fig. 8).

[0033] Fig. 9 is a sectional view of a displacement detecting device incorporated with the above-described pressed optical element 11. In the displacement detecting device, on a base 21, a light source 22 and three light receiving elements 23 are provided. The light source 22 is an LED, a semiconductor laser or the like which emits coherent light with a wavelength of 632.8nm. The base 21 is incorporated with a lens system comprising a spherical lens or an aspherical lens. An optical scale 25 is provided above the lens system 24, and the light emitted from the light source is converged on the lens system 24 and directed to the optical scale 25.

[0034] The optical scale 25 has functions as a phase difference detector and as an oscillation type diffraction grating. The optical scale 25 has a radial periodical grating on a surface of a disc substrate, and for example, the optical scale 25 has a grating 26 composed of 2500 or 5000 V-shaped grooves. The substrate of the optical scale 25 is made of a transparent optical material and is fitted to a rotary member (not shown) so as to rotate together with a rotary shaft 27. Above the optical scale 25, the pressed optical element 11 is fitted in a frame 28 supported by the base 21.

[0035] The pressed optical element 11 is positioned in conformity with a Fourier transformation surface of the grating 26. Light incident to a first area of the optical scale 25 is diffracted by the grating 26. Every element is positioned such that the nth-degree diffracted light (the 0-degree and the $\pm$1st-degree diffracted light L(0), L(+1) and L(−1)) are converged on the optical surface 16 of the pressed optical element 11. The optical axis O of the pressed optical element 11 and the principle ray of the incident light are off from each other.

[0036] The pressed optical element 11 reflects the light (three

kinds of diffracted light L(0), L(+1) and L(−1)) which was diffracted and converged by the optical scale 25 and reproduces an interference image in accordance with the diffracted light on a second area of the optical scale 25. Then, when the optical scale 25 rotates, the interference pattern image moves in the direction opposite the rotating direction. Thus, the grating 26 and the interference pattern image move relatively to each other by double the travel distance of the optical scale 25, and information on the rotation can be obtained at double the resolution of the grating 26.

[0037] The interference pattern image and the light in accordance with the arrangement of the V-shaped grooves of the grating 26 refract geometrically in the second area, and the light emergent from the second area is detected by the light receiving elements 23. Signals output from the light receiving elements 23 are processed in a signal processing circuit comprising a pulse counting circuit, a rotating direction detecting circuit, and thereby, information on the rotation is obtained. Since this displacement detecting device is incorporated with the high-accuracy pressed optical element 11, the displacement detecting accuracy is improved.

[0038] Fig. 10 is a plan view of a pressed optical element 31 according to a second embodiment, and Fig. 11 is a sectional view of the pressed optical element 31. The pressed optical element 31 is a convex mirror and is produced by a similar manufacturing process as described in connection with the first embodiment. The pressed optical element 31 comprises a reference part 32 in the shape of a square pole, a reference face 33, a flat part 34, an optical surface support part 35, an optical surface 36 and a flange 37 which correspond respectively to the cylindrical reference part 12, the reference face 13, the flat part 14, the optical surface support part 15, the optical surface 16 and the flange 17 of the first embodiment. As

mentioned in connection with the first embodiment, the pressed optical element 31 may be a spherical mirror, an aspherical mirror, a free curved surface mirror or the like. Also, from an aspect of optical structure, the pressed optical element 31 may be a concave mirror.

[0039] Fig. 12 shows the structure of an image forming apparatus incorporated with the pressed optical element 31. In an optical path of a laser beam L emitted from a semiconductor laser 41, a collimator lens 42 and a polygon mirror 43 are located in this order. Ahead in the travel direction of the laser beam L reflected by the polygon mirror 43, the above-described pressed optical element 31 is provided. Further, ahead in the travel direction of the laser beam L reflected by the pressed optical element 31, a photosensitive member 44 is provided.

[0040] When an electric signal carrying letter and image data is sent to an interface controller from a host computer, the interface controller processes the electric signal. Then, a laser driving circuit is driven in accordance with an output signal from the interface controller, and the semiconductor laser 41 emits a laser beam L.

[0041] The laser beam L emitted from the semiconductor laser 41 is converged by the collimator lens 42 and is reflected on reflecting surfaces of the rotating polygon mirror 43. The laser beam L reflected by the polygon mirror 43 is reflected by the pressed optical element 31 and is incident to the photosensitive member 44 while scanning in a direction along the axis of the photosensitive member 44. The photosensitive member 44 was entirely electrified uniformly by a charger, and the electric charge on a part exposed to the laser beam L is attenuated, while the electric charge on the other part which is not exposed to the laser bam L is remained. In this way, an electrostatic latent image is formed on the photosensitive member 44 by on/off control of the semiconductor laser 41. Since this image

forming apparatus is incorporated with the pressed optical element 31 instead of a conventional spherical lens and a conventional toric lens, a remarkable reduction in cost and downsizing can be achieved.

[0042] Fig. 13 is a plan view of a pressed optical element 51 according to a third embodiment, and Fig. 14 is a sectional view of the pressed optical element 51. The pressed optical element 51 is a concave mirror and is produced in a similar manufacturing process as described in connection with the first embodiment. The pressed optical element 51 comprises protruding reference parts 52, reference faces 53, a flat part 54, an optical surface support part 55, an optical surface 56 and a flange 67 which correspond respectively to the cylindrical reference part 12, the reference face 13, the flat part 14 the optical surface support part 15, the optical surface 16 and the flange 17 of the first embodiment. Three reference parts 52 are arranged on a circumference at uniform intervals, and three reference faces 53 are on a circumference.

[0043] The third embodiment has the same effect as that of the first embodiment. Further, although three reference parts 52 are formed here, four or more reference parts may be formed.

[0044]

[Effect of the Invention]

As described above, regarding the pressed optical elements according to claim 1, claim 3 and claim 4, the reference part which serves as a reference when the pressed optical element is incorporated into an optical device is formed by drawing, and chips, flash, warp, etc. do not occur. Accordingly, formation of an optical surface and fitting of the pressed optical element into the optical device can be relieved from the influence of the chips, flash, warp, etc. Consequently, the accuracy of the optical surface is improved, and the pressed optical element can be fitted into the optical device accurately. Also, the

rigidity of the optical surface can be improved due to the reference part, and the accuracy of the optical surface after fitted into the optical device can be stabilized.

[0045] The pressed optical element according to claim 2 has a large engagement length toward the optical device, and the tilt of the optical surface can be effectively reduced.

[0046] Regarding the pressed optical elements according to claim 5 and claim 6, the second soft metal substrate guarantees the reflectivity of the optical surface, and the first soft metal substrate supplements the rigidity of the second soft metal substrate. Therefore, the accuracy of the optical surface is improved. Also, because the first soft metal substrate is less costly, the cost of the metal plate becomes less.

[0047] Regarding the pressed optical element according to claim 7, oxidization and corrosion of the second soft metal substrate with a high purity can be prevented, and the antiweatherability of the pressed optical element can be improved.

[0048] In the pressed optical element manufacturing method according to claim 8, the metal plate is sheared after formation of the optical surface, and the optical surface is not influenced by the shearing. Therefore, the accuracy of the optical surface is improved, and the tilt of the optical surface against the optical device can be reduced.

[0049] The displacement detecting device according to claim 9 can detects information on rotation and travel accurately.

[0050] The image forming apparatus according to claim 10 is not incorporated with a conventional spherical lens and a conventional toric lens, and a reduction in cost and downsizing are possible.

[Brief Description of the Drawings]

Fig. 1 is a plan view of a pressed optical element according to a

first embodiment.

Fig. 2 is a sectional view of the pressed optical element.

Fig. 3 shows a composition of a metal plate.

Fig. 4 shows a composition of a metal plate.

Fig. 5 shows a manufacturing process of the pressed optical element.

Fig. 6 is an illustration showing a tilt which occurs when the pressed optical element is fitted into an ordinary holder portion.

Fig. 7 is an illustration showing an error in producing the pressed optical element.

Fig. 8 is a sectional view showing a state where the pressed optical element is fitted in a thin holder portion.

Fig. 9 is a sectional view of a displacement detecting device incorporated with the pressed optical element.

Fig. 10 is a plan view of a pressed optical element according to a second embodiment.

Fig. 11 is a sectional view of the pressed optical element.

Fig. 12 shows the structure of an image forming apparatus incorporated with the pressed optical element.

Fig. 13 is a plan view of a pressed optical element according to a third embodiment.

Fig. 14 is a sectional view of the pressed optical element.

Fig. 15 is a sectional view of a conventional pressed optical element.

Fig. 16 shows a manufacturing process of the conventional pressed optical element.

Fig. 17 is an illustration showing errors in producing the conventional pressed optical element.

Fig. 18 is an illustration showing a tilt which occurs when the conventional pressed optical element is fitted into a holder portion.

Fig. 19 is an illustration showing the operation of the conventional optical element fitted in a holder portion.

[Description of Reference Symbols]

11, 31, 51: pressed optical element

12, 32, 52: reference part

13, 33, 53: reference face

14, 34, 54: flat part

15, 35, 55: optical surface support part

16, 36, 56: optical surface

17, 37, 57: flange

18a, 18b: tie bars

19a, 19b: spaces

21: base

22: light source

23: light receiving element

24: lens system

25: optical scale

26: grating

27: rotary shaft

28: frame

41: semiconductor laser

42: collimator lens

43: polygon mirror

44: photosensitive member

A: metal plate

A1: first aluminum substrate

A2: second aluminum substrate

A3: glass film

L: laser beam

S, S': holder portion